THE QUEEN'S RIVER MORAINE IN RHODE ISLAND.[1]

In the autumn of 1894 Mr. F. C. Schrader and the first-named author of this paper, while traversing the western boundary of the Narragansett basin in Rhode Island, as members of Mr. N. S. Shaler's party, came upon an heretofore undescribed frontal moraine of large bowlders in the town of Exeter, R. I. This moraine is locally known in its strongest development on the south side of Shrub Hill on the farm of Mr. N. C. Reynolds as "Cat Rocks," and at another locality not far northward as "The Queen's Kitchen." (See Fig. 1.) Subsequent to this visit, Marbut undertook under the direction of the senior author to trace out this bowlder belt and to determine the indications, if any, of the front of the ice where the bowldery accumulation was feebly developed or wanting. In the following pages, are stated the observations of Woodworth regarding the moraine at Cat Rocks and of Marbut on the extension of the moraine northeastward and southwestward.

The Queen's River bowlder belt is one of a series of well-developed moraines crossing southern Rhode Island. The outermost of these lines, that of Block Island, is imperfectly revealed. The next in succession northward, the Charlestown moraine, skirting the southern coast, is of the knob-and-basin type and is apparently submarginal in its origin. The Queen's River moraine lies at an average distance of twelve miles north of the last named. Investigation has not yet determined whether there is an intermediate moraine or not. All the moraines thus described lie west of a tolerably well marked interlobate axis passing northward from near Point Judith and thus west of East Greenwich toward Woonsocket. East of this line, the ice ran out through the Narragansett Bay depression in

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the form of a lobe and west of the line indicated lay a wide but less well defined lobe of the ice-sheet. The general relations of the Queen's River moraine to the frontal deposits known in this field are shown on the accompanying sketch map of Rhode

FIG. 1.—Queen's River Moraine, "Cat Rocks." View looking northeast from a point near the top showing the piling of bowlders successively from the north side.

Island (Fig. 2). The moraine is, in general terms, an upland phase of the sand-plains which mark the frontal stages of the ice-sheet in the Narragansett Bay region. The Queen's River moraine is probably contemporaneous with one of the frontal deposits which occur in the vicinity of Wickford Junction on the east side of the interlobate axis named.

Inasmuch as the bowlder belt at the Cat Rocks locality presents a form of accumulation capable of a somewhat extended diagnosis and furnishes criteria for determining the relations of

the deposit to the ice-sheet, the main features will be discussed somewhat at length.

The bowlder belt lies on the southern slope of Shrub Hill.—The accumulation of bowlders marking this moraine has taken place on the southern slope of a range of low crystalline hills forming the northern side of the river valley. The elevation above the

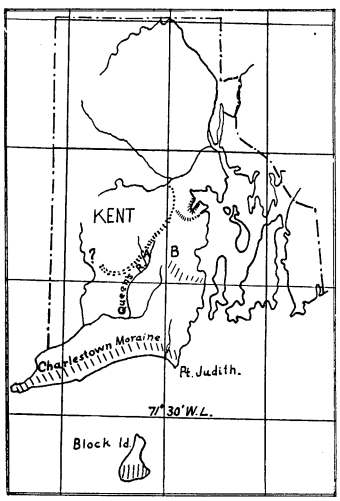

FIG. 2.—Sketch map of Rhode Island showing Queen's River bowlder belt. A, Cat Rocks in Exeter. B, Wickford Junction and Congdon Hill moraine. The small hachures northward indicate frontal deposits near East Greenwich.

stream varies from 20 to 100 feet. At Exeter the line crosses the river. Except for the excessive development of bowlder accumulations along this line, the surface deposits of till both north and south of the belt for several hundred feet would be classed as ground moraine, probably in part englacial till with subglacial material underlying it, the product of the melting out of an indefinite mass of ice.

The occurrence of bowlder belts in Southern New England on the crest of hills or on their southern slopes has been remarked elsewhere, as on Cape Ann by Shaler and Tarr, and on the southern slope of the highlands of Martha's Vine-

yard.[1] There appears to be a causal relation between the local conditions of this position and the deposition of the bowlders from the front of the ice-sheet. A brief analysis of the conditions which may be assumed to arise in such a position is appropriate in this place.

The stand of the ice front at the time of formation of the bowlder belt may be assumed to indicate that for the time being the rate of forward movement of the margin of the ice was equaled by the rate of melting back of the front. There are several reasons for believing that the ice was moving forward at this time. As will be presently explained in detail, the attitudes of some of the bowlders in the moraine at Exeter suggest the application of force in this manner. Had the ice been stagnant, the bowlders distributed in and under it or upon it, would have come to rest as a sheet of discrete bowlders instead of being brought up to a given line and there deposited.

The moraine was formed on that side of the valley which receives the larger amount of insolation. It is to be inferred from this that the same ice front lying upon the southern side of the valley with a less insolation to be reflected against the ice or received upon it would not have melted it back at a rate equal to the forward motion of the front; that the ice would, therefore, have moved over the crest to the next southern slope, where the insolation rate would again equal the forward movement and the ice be brought to a stand. On southern slopes the forward movement of the margin of the ice would be accelerated by gravity, on northward slopes retarded. But the tendency of a northward slope to retard would probably in time be overcome by the push of the ice from behind, while the acceleration on a southward slope would give an actually increased movement. With a balanced ice front on the northern side of the valley, it is therefore probable that the line of halt along the north side of Queen's River Valley indicates a slight advance of the ice front from the country on the north and not an

[1] See forthcoming atlas folio report on surface geology of Martha's Vineyard, by J. B. Woodworth.

immediately preceding retreat from the country lying south of the river.

To this consideration should be added the effect probably arising from the drainage in the valley which would tend to

FIG. 3.—View along the crest of Queen's River moraine showing its massiveness (here about 150 feet wide). The trees are growing from soil accumulated between the more closely set bowlders.

weaken and remove the ice in that position and to increase the frontal melting rate of an ice-sheet advancing into the stream from the north, so that the ice front would from this cause tend to rest along the northern bank. The elevation of the belt above the present stream does not preclude the existence of water at that height in glacial times.

Bowlders are scattered along the front of the belt.—South of the line of piled bowlders is a fringe from one to two rods wide

in which bowlders are scattered as if they had rolled out of a vanished cliff on the north. These fragments vary greatly in size. Their general appearance is shown in Fig. 3, a view taken from the crest of Cat Rocks.

Bowlder Couplets.—Within this fringe and particularly near the line where the materials begin to exhibit superposition, instances may be observed where bowlders occur in pairs: a

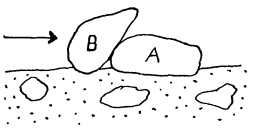

FIG. 4.—Bowlder Couplets. A, the stop; B, the stopped bowlder. The arrow indicates the direction of movement.

firmly settled bowlder has one leaning against it on the northern side, as indicated in the accompanying diagram (Fig. 4). These couplets appear best explained by supposing that the leaning bowlder tumbled outward from the ice and was stopped by coming into contact with the block on the south which had preceded it. The association of these colliding couplets with the scattered bowlders above described suggests the probability that the fringe as a whole is due to the falling out of bowlders from the ice front.

The structure of the main wall.—The belt at Cat Rocks is accumulated on a slope, so that while the crest is upwards of thirty feet above the frontal fringe by the roadside on the south, the elevation of the inner mural margin is not more than from three to six feet. The thickness of the belt, however, in places must be from ten to fifteen feet or even more, for the bottoms of the holes between the larger bowlders have not yet been reached with certainty. Many of these spaces are so large as to permit of the entrance of three or four persons with a little inconvenience. The absence of fine materials in the belt is very conspicuous. Although many trees are seen growing up out of the belt, most of them are probably growing out of a soil

which has formed in the lower part of the hollows and not from the soil proper of the surface on which the belt rests. One large oak has grown out of a crevice in a large bowlder, with a result in the end fatal to the tree.

FIG. 5.—View of the Queen's River moraine. "Cat Rocks," from the intra-glacial field north of it, looking at the inner edge of the bowlder wall and showing the line along which the mural (?) front of the glacier stood.

The bowlders in many places along the frontal aspect of the moraine, as shown in Fig. 5, exhibit a mode of piling which seem to the writers accountable only on the supposition of addition from the north. Some of the bowlders may owe their peculiar orientation to a slight forward shoving movement. The general scheme of arrangement is shown in the annexed dia-

gram, Fig. 6, representing the highest part of Cat Rocks. The structure of the bowlder belt at Cat Rocks is, therefore, wholly consistent with the theory of its glacial origin, and the evidence of this exists not only in the main pile but also in the fringe above described.

It would throw some light on the mode of accumulation of these bowlders if it could be determined whether they were

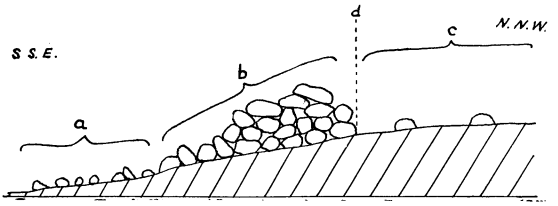

FIG. 6.—Diagrammatic section of highest part of Cat Rocks. A, zone of small scattered bowlders. B, zone of piled bowlders. C, zone of scattered bowlders left by the melting of the ice-sheet. D, position of the ice front.

dropped from an ice cliff as englacial or superglacial matter or were extruded from the base as subglacial débris. It was hoped that we might find criteria in the occurrence of bruised markings due to the violent contact of bowlders which had fallen out in the process of accumulation. The weathering of the blocks, which are largely gneisses and coarse granites, has, however, proceeded so far as to remove the original surface of the rocks where exposed to view, and the points of contact of the larger bowlders are not accessible for examination; so that this point has not been determined.

The northward or inner edge of the belt exhibits a mural contact with the ice front.—No feature in the distribution or accumulation of the bowlders at Cat Rocks is more suggestive of the glacial origin of the accumulation and of the particular relation of the deposit to the ice-sheet than the sharply defined northern wall which is here and there shown. The photograph reproduced in Fig. 5 is a view taken from the intraglacial field about seventy-five feet north of the moraine looking S. S. E. at this mural inner edge where best developed. Nowhere on the

southern side have we seen this phenomenon exactly reproduced. Evidently this mural face indicates the exact front of the ice-sheet at this locality. This wall is then the equivalent of the ice-contact slope at the head or northern side of glacial sand plains and esker-fans. North of this wall lies the intraglacial field, south of it the extraglacial field of that stage of the ice-sheet. It is a line supplying a base of reference from which to work out the relations to the ice-sheet of all associated deposits of the same stage.

North of the bowlder belt, bowlders are scattered as in ordinary ground-moraines.—The bedrock immediately back of the mural inner edge of the moraine is covered by till, the surface of which is pierced by a few scattered bowlders, usually smaller than those in the moraine. Fine materials are in excess. All the indications for hundreds of yards northward indicate a gradual melting down of the ice-sheet or a uniform retreat of the front so as to spread an even coating of till. As to whether the ice disappeared from this particular field by actual retreat of the front or by a general melting down of the whole mass, we have at present no criteria on which to base a decision. There are no indications of distinct submarginal accumulations of the nature of morainal mounds or kame-moraines interior to the frontal bowlder belt. But for the presence of the bowlder belt, one would not, we think, be able to demonstrate the halt of the ice front along this line.

The extraglacial field of the moraine.—South of the belt, there is a gentle slope to the valley of Queen's River, a small stream entering the Pawcatuck. This slope is till-covered to the upper limit of the stratified gravels and sands in the valley. Here and there patches of bowlders occur south of the main belt, in a few places running out like tongues from the moraine, as if along lines of maximum load in the retreating ice.

The outwashed gravels and sands of this stage were not in most of the area built up to the level of the base of the ice on the hillside, so that none of these deposits exhibit sand plains with ice-contact or kame-like slopes on their northern or ice-ward aspect.

Extension northeast of Cat Rocks.—The best development of moraine north of Cat Rocks is at the Queen's Kitchen, about a mile and a half northeast of the village of Exeter. The name is applied to the most northeasterly of a range of three small hills all of which are largely or wholly morainal. They lie on and rise above the surface of a long gentle, southeastwardly sloping plain. North of the moraine the plain is dotted with bowlders and contains many bowlder-filled swamps. South or southeast of the moraine, however, the surface is smoother, the valleys all contain water-laid drift, and bowlders are not so abundant. Bowlders occur occasionally in small patches especially in the heads of shallow valleys though they are of small size.

The moraine stands sharply above this plain, the highest of the three hills rising about sixty feet above the plain at its base. The most southwesterly of the three hills is lower and longer than the others, rising about thirty feet above the surface of the plain on which it stands. It is covered by till carrying a large number of bowlders. No outcrops of country rock were seen though they were not carefully hunted for. The trend of the hill, like that of the range, is about 25° east of north and its length is about 800 feet.

The middle member of the range is a small approximately conical hill about twenty-five feet high and not more than 200 feet in diameter at its base. It is not indicated on the Rhode Island topographic map. It lies about 300 feet north of the last one, and a little way back from a line joining the crests of the other two hills. It contains a larger proportion of bowlders than the last one.

The other member of the range, and the one to which the name Queen's Kitchen is applied, is the highest of the three. It lies about 1200 feet northeast of the crest of the first one described and rises about sixty feet above the plain at its base. Its whole surface is covered with large bowlders with no fine material near the surface. To all appearances the whole hill is merely a pile of bowlders varying considerably in size but all of them large. The northward slope is steep. The bowlders are not scattered out over the plain in this direction so that the

change from the even till plain to the bowlder-covered hill is sudden. The southern slope is more gradual. The bowlders are strung out southeastwardly from the foot of the hill for a distance of several hundred feet. At the foot of the northern slope there is a considerable accumulation of bowlders but they lie just at the foot of the hill and are not scattered out over the plain. They are in just the attitude that they would assume if they had been

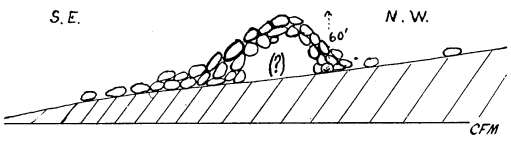

FIG. 7.—Diagram of the Queen's Kitchen phase of the moraine.

piled up against the steep front of the ice and had fallen down when the ice receded.

At Cat Rocks the moraine is accumulated on a locally steeper slope than the general slope of the plain, so that the top of the accumulation rises little if any above the level of the plain on its northern side while at Queen's Kitchen the moraine rises sharply above the plain on all sides. (Fig. 7.)

Between Cat Rocks and the Queen's Kitchen no well-defined bowlder moraine exists. There is, however, a well-defined southern limit in the bowlder-dotted till plain lying north of the supposed position of the ice front. To the south of an irregular line connecting the two localities, the surface drift is water-laid; to the north it is ice-laid. South of this line, bowlders are never seen, excepting scattered ones lying on the higher lands. North of it they are thickly strewn over the surface. It does not appear that the thickly bowlder-covered phase of the till plain extends southward beneath the gravel and sand deposits. South of the northern border of the water-laid drift there are numerous hills which rise well above the level of this deposit, but they carry few bowlders. They all have a smooth outline with only a veneer of drift and the country rock is exposed in many places on them.

North of the Queen's Kitchen there is no prominent bowlder

accumulation along the line of the moraine, though the line limiting the bowlder-dotted till plain on the one hand and the sand and gravel plain on the other is more marked, for a short distance, than it is between Cat Rocks and the Queen's Kitchen.

From the latter place the moraine turns almost due northward and is easily traced for about two miles. It lies along the slope where the higher till-covered plain west of the moraine descends to the lower sand-covered plain east of it. Bowlders are scattered thickly over the slope but they are accumulated very little more along the outer margin than further back. Spurs of the upland, however, which extend out eastward beyond the moraine do not carry many bowlders.

About half a mile south of Frenchtown, the line apparently turns westward along the southern slope of a valley occupied by an eastward flowing stream. An attempt was made to find the moraine north of the valley but it could not be found. The country as far north as Natick on the Pawtuxet River was searched but it was not found. The river was followed up to half a mile above Coventry. Here a line of bowlders crosses the river, having a northwesterly trend, but no attempt was made to follow it in either direction.

Extension south of Cat Rocks.—The moraine was traced southwestward from Cat Rocks to within about three miles of Wyoming in the town of Richmond. Over the greater part of the distance it is a fairly-well marked feature, though it never assumes the phase so well developed at Cat Rocks. As a rule, the relations of the morainal and the extramorainal areas are essentially the same as they are north of Cat Rocks. North and northwest of a somewhat irregular line lies a plain of typical bowlder till on which bowlders are most abundant along the southern margin; south and southeast of it lies a region whose valleys are partly filled with water-laid drift, and whose higher lands consist of rounded hills and ridges carrying very few bowlders. The general relief is the same on both sides of the line. The glacial deposits are not thick enough to hide the preglacial topography. The contrast in appearance between the

plains on the two sides of the ice margin is merely one of surface character. One is smooth, the other is bowlder-covered.

From Cat Rocks southwestward for about two miles the southern margin of the till plain is not sharply defined. It graduates southward into the sand and gravel plain, and bowlders are nowhere abundant. This phase is succeeded by a belt extending southwestward to within one and a half miles of Glen Rock village. The southern border of the till plain is characterized by a thick accumulation of bowlders, almost entirely covering the surface, but not piled up into a ridge. The margin lies along the southern slope of a hill, but it lies north of the northern border of the water-laid drift. Occasional patches of bowlders lie between the margin of the bowlder belt and the northern margin of the water-laid drift.

About a mile and a half north of Glen Rock village, the moraine turns westward, crossing Beaver River at Hillsdale. The upland east of Hillsdale is covered with bowlders and the streams are all filled with them. The ponding of the head waters of a small brook which flows into Queen's River at Glen Rock is probably due to morainal accumulations.

Between Hillsdale and the schoolhouse, a mile and a half north of Glen Rock, the moraine is not so well defined as it is further eastward. The bowlders are neither so abundant nor so large. At Hillsdale, however, it again becomes a characteristic bowlder belt. The morainal accumulation consisting mostly of bowlders has ponded the river. The power thus made available was formerly utilized in manufacturing. Down stream from the moraine the valley is filled up to the level of the foot of the moraine with a broad sand plain, but north of it the valley is filled with bowlders. On the slope of the western side of the river valley just back of the village there is an accumulation of very large bowlders, approaching the phase of the moraine developed at Cat Rocks. From this point westward as far as the moraine was traced its development was weak.

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